

Land Reclamation using Construction Waste for Offshore Gaza Fishery Port

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Abstract : *The world experience rapidly growing in population density and lack of areas especially coastal areas, which is considered the most vital, economic and cultural areas around the world. This force the experts investigating different suggestions such as sea reclamation and its exploitation for many goals.*

Gaza Strip is considered one of the most densely area in the world. Where the population is nearly two million inhabitants by 2016 while the area is 365 square kilometers. This reflects on the availability of lands in the future that will raise the lands prices. Moreover, the existing fishery harbor constructed in 1994–1998 period has locally disturbed the coastal erosion and sedimentation pattern and resulting in sand erosion problems. On the other hand, two million ton of debris have been accumulated in the last aggression on Gaza Strip in 2014. This massive volume of concrete rubble is considered huge burden on the landfills in the Gaza Strip, which are already overloaded. In this study, an investigation of the best way to dispose these debris by land reclamation in Gaza Strip.

In this study, it is proposed to relocate the construction features of the Gaza fishery port for better sediment transport and hydraulic conditions. Therefore, the study methodology started with estimation of the construction waste quantity resulted from 2014 aggression, then ensuring its testing results, specifications and possibility of using it in land reclamation. Furthermore, the existing Gaza fishery port sediment transportation and features were studied and its bathymetry was identified. As a result, the new proposed reclaimed area was identified in west of the existing western breakwater at Gaza fishery port and its area was estimated according to estimation the quantity of debris resulted from removing the existing breakwaters in addition to construction wastes resulted from 2014 aggression. The total estimated quantity of available debris is about one million cubic meters, which adequate to reclaim about 11 hectares. However, the new reclaimed area should be surrounded by sheet piles, so the sheet pile type is assumed to be PZC 28 and finally the total cost of the proposed reclaimed area was estimated as USD130 per square meter of reclaimed area. Finally, to facilitate transportation and movement through this reclaimed area, the bridge is recommended to be constructed. Finally, the cost of sea reclamation is feasible especially that Gaza fishery seaport is very vital and important place, which will be as a fishery port and for recreational activities.

Keywords: *Land reclamation, construction waste, Gaza fishery port*

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1. INTRODUCTION

More than one-third of the world's population resides in coastal areas, which account for just 4% of Earth's total land area. Coastal population densities are nearly three times that of in land areas and are increasing exponentially. Coastal human settlements usually exploit their position by reclaiming tidal and shallow sea areas through land reclamation. This phenomenon can be observed in many coastal countries and cities, such as Korea, Japan, Singapore, the Netherlands, Hong Kong and Macau (Feng et al., 2014).

Reclamation in coastal zones is effective for relieving population pressure and ensuring food safety. Since the 1950s, the development of coastal zones has entered a peak period. At present, the reclamation of coastal zones mainly occurs in developing countries. The coastal reclaimed lands are mainly used for agricultural production, urban and industrial development, and port construction (Li et al., 2014). Land reclamation is a process to create new land from the sea, which can be achieved with several different methods. The simplest method involves simply filling the area with large amounts of heavy rock and/or cement, then filling with clay and dirt until the desired height is reached (Nadzir et al., 2014).

As coastal area is a very sensitive area, any development needs to be highly evaluated for its possible disturbances. It is because the coastal reclamation comes with its adverse impacts to the land. Hazard in the coastal area found through erosion activity and caused by environmental change and human actions. If ecosystem undermined, the ability of the coastal areas to adapt and regenerate would erode (Nadzir et al., 2014). The conversion of sea to land permanently changes the natural characteristics of the ocean and coastal environment and cause considerable damage to the marine ecosystems upon which human kind depends. The impacts of reclamation not only limited to the area where damped/dredged and reclaimed occurred, but impacts felt over a larger area where siltation or change in current happened (Azwar et al., 2013).

This study investigates in focus the feasibility of sea reclamation practices in the Gaza strip where due to the lack of lands for several activities pushes the decision makers toward sea reclamation. Gaza strip is considered as one of the highly populated density areas around the world, where the population is nearly 2 million inhabitants by 2016 while the area is 365 km² (PCBS, 2016). The implementation of such reclamation projects can be considered as an urgent to Gaza strip, for a number of reasons. The main of these reasons are the increasing in population growth, the economic recession and lack of areas.

Indeed, the coast of Gaza was affected by man-made structures such as the construction of fishery harbor, which started in 1994 and completed in 1998. The fishery harbor has locally disturbed the coastal erosion and sedimentation pattern and resulting in sand erosion problems. Furthermore, the building and roads adjacent to the shoreline are facing a stability problem and it is expected to have

a serious erosion problem in the coming few years specially in the region of Beach camp that locates to the north of the port's site (Abualtayef et al., 2012). As a counter-measure to this, the construction waste was deployed in the eroded area, which works as a beach revetment, to mitigate the severe beach erosion and protecting the hotels. UNRWA has constructed gabions along the Beach camp with a total length of 1650 m to protect 3 the main coastal road. Several short groins have been constructed along the Beach camp for shoreline preservation. Actually, these mitigations are not effective and hence significance measures should be under taken to protect the beaches against coastal processes due to the fishery harbor (Abualtayef et al., 2012).

On the other hand, due to the three aggressive invasions that occur in Gaza strip in 2008, 2012, and 2014, about two million tons of debris have been accumulated in the lands from damaged buildings and facilities. However, the last war on the Gaza strip was one of various rationales that played big role in deteriorating infrastructure conditions in the strip. The ten-year closure had already left most of infrastructure facilities inadequate to function. In particular, municipal services, especially solid waste and solid waste treatment, had to be curtailed, leading to the accumulation of hundreds of tons of rubbish on the streets each day. Restrictions on the imports of essential consumables and other materials also reduced the efficiency of the operation of sanitary landfills and garbage collection trucks. (UNDP, 2014).

To overcome solid waste storage problem, Municipality of Rafah was the first who carried out crushing activities in relatively large quantities. Funded by Italian Government, the municipality was supplied by a small-scale crusher capacity of 70 tons per hour and started crushing of concrete rubble generated in the south of the Gaza strip. The produced crushed material was used by the municipality in agricultural roads. Later, a small quantity was used by UNRWA in some roads in Tal Sultan area in Rafah. The next large-scale crushing of concrete rubble was followed by UNDP after disengagement of Israeli occupation from Gaza settlements. In 2006, UNDP was assigned by quartet to remove and crush more than 700,000 tons of mixed concrete rubble from Gaza settlements. Nearly 400,000 tons of this rubble was removed in very good and clean conditions (UNDP, 2014).

In general, two million tons of construction waste that was generated from the last war on Gaza. One of these problems is how and where to dispose this massive volume of concrete rubble taking into consideration that almost all available landfills in the Gaza strip are already overloaded. The Palestinians ministries proposed many ideas to effective disposal for this debris. In this study, an investigation of the best way to dispose these debris by land reclamation in Gaza strip especially that the huge need to mitigate the problem of the existing Gaza fishery port.

2. MATERIALS AND METHODS

Producing of reusable crushed material was an essential step to obtain the best benefits from generated post-war rubble such as reducing the total volume of the rubble in already overloaded landfills and bridging the gap between demand and supply of construction aggregates in construction demand industry taking into consideration performing required tests that approve the application of such recycled materials.

In 2009, the quantities of debris were gathered from UNDP and other relevant authorities in the Gaza strip. Then, the samples were taken by two teams from IUL and AEL labs arranged for taking a sample from 30,000 tons of crushed materials from post-war rubble. The objective of testing crushed materials was to determine the technical applicability of using the recycled concrete rubble collected from post-war affected sites in Gaza strip in road construction as an alternative for the natural 4 aggregate in road construction or other applications. The characteristics of such aggregates were determined and compared to international standards. The reuse alternative was investigated in road and concrete construction throughout all performed tests. The test analysis showed that the recycling of the concrete rubble aggregates and its use in road sub-base give acceptable results. Thus, recycled aggregates can be considered as a good alternative to natural aggregates especially in road constructions.

2.1 Site bathymetry

The bathymetric features of the Gaza fishery port were gathered by real field survey using sonar as it shown in Figure 1.

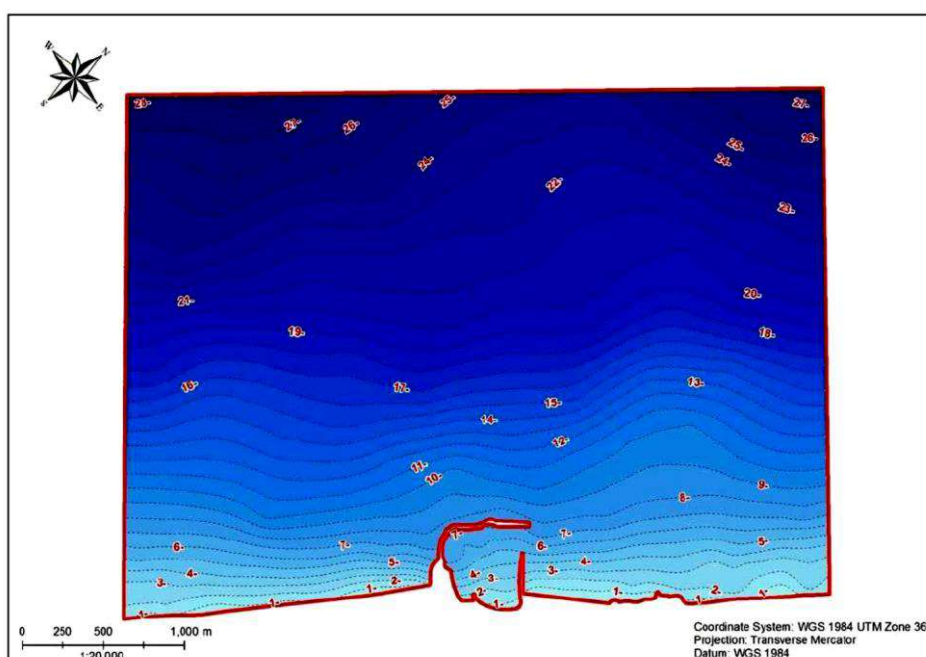


Figure 1: The bathymetric features of the Gaza fishery port

2.2 Materials and rubble quantities

The 51-day, July-August 2014, military operation in the Gaza strip has caused the destruction of infrastructure and buildings. In order to verify the preliminary infrastructure damage assessment findings and to further inform on the actual damages, the Higher Inter-Ministerial Committee tasked UNDP to conduct a detailed infrastructure damage assessment in collaboration with line ministries, UNRWA, UNOSAT and WFP. UNDP estimated that around two million tons of rubble have been generated, which is three times more than the amount of rubble generated during 2008-09 Gaza war. The detailed quantity of generated rubble according to the Gaza strip governorates is shown in Table1 (UNDP, 2016).

The analysis results of specific gravity for the crushed material is 2.35, accordingly the available volume of filling material for reclamation is about 850,000 m³ (UNDP, 2016).

Table 1: Detailed quantity of generated rubble

Governorate	North	Gaza	Middle	Khanyounis	Rafah	Total (Actual)
Total Rubble (×10 ³ ton)	548	611	148	382	287	1,976
No. of Buildings	352	352	121	329	341	1,495

2.3 Characteristics of debris

UNIDO (2005) conducted a testing program to investigate the application of construction and demolishing wastes in construction industry in the Gaza Strip. The performed testing program aimed to highlight the possibility of producing recycled aggregates from the construction and demolition wastes (CDW) and was performed on a sample taken from concrete rubble in Rafah area. The reuse alternative is investigated in concrete mixes and road construction throughout comprehensive testing program. The test results showed that the recycling of the CDW aggregates and its use in both concrete and road subbase gives acceptable results.

Furthermore, UNDP (2009) conducted testing program on samples were taken from concrete rubble that collected from post-war rubble. The results show good opportunities for using crushed concrete rubble in construction industry. Many tests were performed taking into consideration previous international experience in this field where more than 900 million tons of concrete rubble is annually generated and partially reused in USA, Europe and Japan.

Sieve analysis: The collected samples of crushed concrete rubble were sieved, and the results were compared with the standard limits of AASHTO for base course and sub-base materials grade

(A). as a result, the samples showed that they were going down to lower standard limit which represents the course limit. Some of the samples were courser than the standard limits and others were slightly matching these limits. From technical point of view, this gradation is acceptable to some extent. The large particles, greater than 2.5 cm are suitable for road applications However, for concrete application it is recommended to use small particles, smaller than 2.5 cm. For concrete application it was recommended to conduct three tests: compressive strength test at 7 and 28 days, slump test and air content test. Physical properties of these fractions as obtained from previous studies are shown in Table 2 (El Kharouby, 2011).

Analysis of gradation: Results of the sieve analysis road applications showed that the crushed material is classified as coarse material greater than 4.75 mm (sieve no. 4). As shown in Table 3, the coarse to fine materials ratio was on average 77% to 23%, respectively (El Kharouby, 2011). The amount of course materials according to AASHTO should not exceed 70% and for fine materials 40%. This means that an additional amount of fine materials should be added to meet the standards. Table 4 6

shows the test results for other essential requirements of crushed concrete comparing to international standards (El Kharouby, 2011).

Table 2: Physical properties of concrete aggregate fraction

Type	Size fraction (mm)	Fineness modulus	Unit weight (kg/m ³)	B.S.G	Absorption (%)
Type 1 (Folia)	25.0-4.75	7.42	1478.5	2.65	3.13
Type 2 (Adasia)	12.5-4.75	6.89	1468.1	2.60	3.00
Type 3 (Semsemia)	9.5-2.36	5.72	1526.6	2.55	2.00

Table 3: Course and fine aggregate contents

Lab name	Coarse aggregate (%)	Fine aggregate (%)
Islamic University Laboratory	82	18
Association of Engineers Laboratory	71	29
Average	77	23

Recycled concrete rubble seems to have satisfying properties for the most common exposure conditions. It can solve many of the basic problems concerning shortage of construction materials in roads and concrete construction and reclamation. In addition, as natural resources diminish, the demand for recycled concrete aggregate is likely to increase, making concrete

recycling the economically and environmentally preferable alternative to traditional “smash and trash” demolition. Wherever good natural aggregates are not locally available, where natural aggregate costs exceed removal and recycling costs or where disposal of existing concrete pavement or concrete structures is problematic, concrete recycling should be evaluated. Moreover, concrete recycling appears to be profitable. In most cases, it can meet demand requirements of lower value product applications such as land reclamation.

2.4 The study methodology

The characteristics results of concrete rubble showed the possibility of using it in sea reclamation. Therefore, sea reclamation will be the best solution to alleviate these problems. The study methodology was implemented as in the following steps: estimating the total quantity of rubble resulted from the 2014 war on Gaza strip, testing characteristics of concrete rubble for sea reclamation possibility, studying the existing fishery harbor area and characteristics to determine the suitable interventions and which tongues will be removed, defining the bathymetric features of the Gaza fishery port by real field survey using sonar to determine the sea water depth at different points as it shown in Figure 1, estimating the rubble quantity resulted from removing the existing breakwaters of the Gaza fishery harbor, estimating the total rubble quantity will be reclaimed by adding the previously estimated removed rubble quantity to the resulted from the 2014 war on Gaza strip. Defining the proposed reclaimed area dimensions and estimating its area as it shown in Figure 2, choosing the suitable sheet pile needed to reclamation based on the soil type, seawater depth and loads; cost estimation of the proposed area reclamation, and finally defining the trucks movement and routes during reclamation implementation.

Table 4: Test results of essential characteristics of concrete rubble

Test Name	Standard	Average Result	Standard Requirements
Liquid limit, %	BS 1377	20.25	According to AASHTO and ASTM for sub-base and base materials, this value should not exceed 25%.
Specific gravity	ASTM-854	2.35	Lower than crushed natural rock stone
Absorption, %	ASTM-2216	5.55	
Finer than #200 Sieve, %	ASTM-1140	1.95	
Clay lumps & friable particles, %	ASTM-142	0.15	According to BS 882:1992, this value is very low which this is advantage for construction application.
Flakiness index, %	BS 812	24.5	According to BS 882: 1992, this value should be less than 40% for road construction.
Elongation index, %	BS 812	9.1	According to BS 882: 1992, this value should be less than 40% for road construction.
Max. dry density, gm/cm ³	ASTM-1557	1.97	Local CODE 2.15%
Optimum water content, %	ASTM-1557	10.25	
Los Angeles Abrasion test, %	ASTM-131	41.75	AASHTO maximum allowed value, to be used in the road construction as base course material is 45% at 500 Rev.
California Bearing ratio, CBR at 100 Rev., %	ASTM-1883	163	Minimum required value (80%) for base course at 100% compaction according to AASHTO (T180-D) and T193.
Sand equivalent, %	ASTM-2419	66.6	Local standards for base course: Minimum 35% sand equivalent at any stage of road construction.
Impact value, %	BS 812	28	According to BS 882: 1992, this value is suitable.
Crushing value, %	BS 812	26.15	



Figure 2: The proposed reclaimed area for offshore Gaza fishery port

3 RESULTS AND DISCUSSION

Gaza fishery harbor considers the only port for the ships and boats of Gaza's fishers, but unfortunately this port causes significant problems of erosion/accretion along Gaza's coastline. In this regard, the coastal researchers studied in deep several alternatives to relocate/redesign the port in order to mitigate its impacts on the coastlines and nearby structures. 8

Abualtayef et al. (2013) recommended that relocating the current situation of Gaza fishery harbor into offshore fishery harbor is the most suitable alternative to mitigate the erosion/accretion impacts, but the main obstacle of this design is the generation of strong current of 1.0 m/s at the entrance of the harbor. However, this obstacle can be overcome by some arrangements of structures. So, this section explains and discuss the estimation process of the proposed reclaimed quantity and area in addition to estimate the reclamation cost.

3.1 Existing breakwaters quantity estimation

The quantity of construction wastes that intent to be used in relocating the current design into offshore fishery harbor is 850,000 m³. Fortunately, the reclaimed area can be increased if we exploit the used materials in the 300 m and 500 m breakwaters as shown in Figure 3.

To calculate the volume of rubble resulted from removing the 300 m and 500 m breakwaters extended from the beach, it assumed that this area is divided to three different segments areas; A, B and C, then their dimensions is shown in Figure 4. After that, the area of each segment is calculated as shown in Table 5.

Table 5: Volume estimation of rubbles resulted from removing the breakwaters

Segment	Area m×m	Average depth m	Volume m ³
A	300 × 20	4.5	27,000
B	$\frac{1}{2} \times 180 \times 329$	5.0	148,050
C	175 × 20	8.5	29,750
Total			204,800



Figure 3: The existing Gaza fishery harbor
(source: Google earth, 2016)

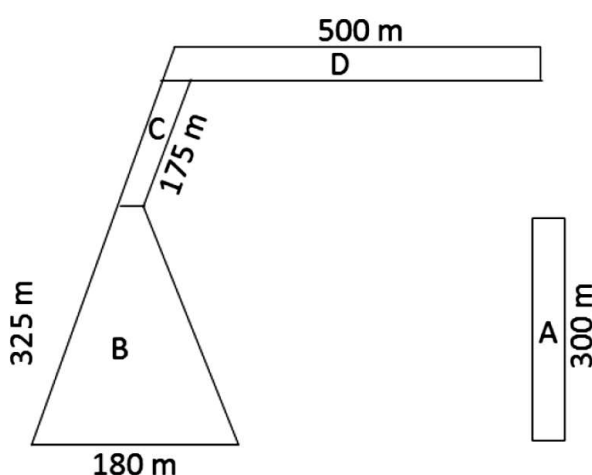


Figure 4: Illustration of the dimensions of breakwaters in existing Gaza fishery port

Based on the calculated volume for each segment, the total volume of rubble produced from removed these three segments is 204,800 m³. In addition, the available volume of rubble accumulated from the last 2014 war on Gaza Strip is approximately 850,000 m³. Therefore, the total available rubble volume for proposed reclaimed area is more than 1.0 Million m³.

3.2 Estimation of the proposed reclaimed area (new offshore Gaza fishery port)

The required area for proposed reclamation is calculated by using the total amount of produced rubble, which previously estimated as 1,053,000 m³.

According to the contour map is shown in Figure 1), the seawater depth at 500m, 600m and 700m away from the beach are -7m, -8m and -9m respectively. However, the existing breakwater ground is 2m above sea water level.

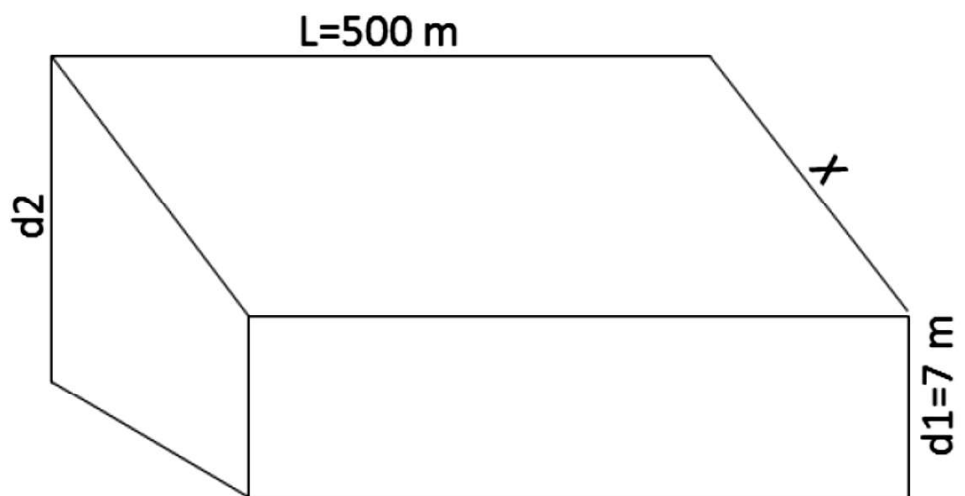


Figure 5: Dimensions of proposed reclaimed area

To calculate the required area as it shown in Figure 5, the following equation is used:

The volume of new reclaimed area =

$$\left[\frac{(d1+2)+(d2+2)}{2} \right] \times X \times L$$

d1 is the seawater depth at 500 m away from the beach, which is equal to 7 m

d2 is the seawater depth at the end limit of the proposed reclaimed area

X is the width of the reclaimed area

L is the breakwater length (also the length of the reclaimed area), which is 500 m

by substitution with these values and using the volume of new reclaimed area of 1.0 million m³, the resulted equation with two variables is solved by goal seek on excel program and keeping the minimum width of the reclaimed area 200 m. the resulted value of d2 and x are 9 m and 208 m, respectively.

As the width of existing breakwater segment D (Figure 4) is 20m, the total width will become 228 m and length of 500 m.

3.3 Cost estimation of proposed reclaimed area

Rubble transportation cost estimation

Based on the coordination with rubble relevant sectors, the accumulated rubble from the last war in 2014 on Gaza Strip is considered available. So, the accumulated rubble will be transported to the project site by assumption that the truck capacity is 16 m³. As the cost of one truck trip is about 65\$ and as the total quantity need to transport is 1,000,000 m³, so the required trips number is 65813 trips. The total transport cost is 4.3M USD. The filling and damping cost is estimated to be 200% of transport cost, so the total needed cost 8.6M USD.

Sheet piles cost

It is assumed that the need sheet pile section is PZC 28 as it shown in Figure 6. The weight of 1 square meter of PZC 28 section is 166.1 kg/m². The reclaimed area shape is rectangular, with the total perimeter of 1,456 m $([500+228] \times 2)$. Assuming the average seawater depth at the new reclaimed area is 8 m and as the existing breakwater ground is 2 m above seawater level, the sheet pile will be installed at 5 m underground, so the total height of the installed sheet pile is 15 m. The total weight required of sheet pile 3630 tons $(1457 \times 15 \times 166.1)$. The cost of PZC 28 sheet pile section is about 550\$/ton. So, the total cost of need sheet pile steel is 2M USD.

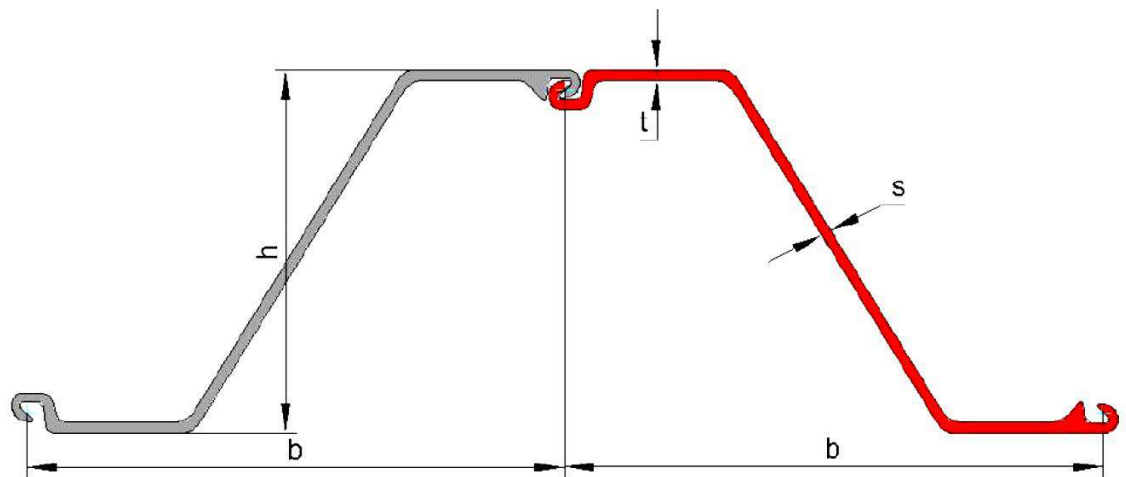


Figure 6: The proposed sheet pile section (PZC 28)
 (source: GERDAU, 2016)

Sheet pile installation cost

In common, the sheet pile installation cost at the site is about 300% of the sheet pile steel cost. So, the installation cost is 6M USD.

Finally, the total cost of the new reclamation area is equal to the summation of rubble transportation to the site project cost and installation of sheet pile steel cost as shown in Table 3. Therefore, the total project cost is 14.6M USD. In conclusion, as the total reclaimed area is 114,000 m² (500×228), the cost per square meter of reclaimed area is 130 USD/m².

Table 6: Summary of cost estimation of proposed reclaimed area

Item	Cost M USD
Rubble transportation and dumping cost	8.6
Sheet piles installation cost	6.0
The total cost of the proposed reclamation area	14.6
The cost of one square meter of reclaimed area	130 USD/m ²

3.4 Proposed reclamation process

- Defining the proposed reclaimed area that is the area located in the west of the existing western breakwater.



Figure 7: Illustration of the proposed reclaimed area location and method
(source: DEME, 2014)

- Choosing the sheet pile needed to reclamation based on the soil type, seawater depth and loads. Therefore, the chosen sheet pile type is hot rolled steel sheet pile PZC 28. The sheet pile installation will be around the entire proposed reclaimed area.



Figure 8: Installation of sheet piles
(source: WIKI, 2016)

- Defining the trucks movement and routes during reclamation implementation, which will be through segment B to segment C to fill the area located on front of segment D.



Figure 9: The trucks movement during reclamation process
Source: (Yin Pumin, 2014)

- The reclamation steps will start with using the rubble resulted from 2014 war on Gaza Strip, then continuing reclamation by using the rubble from removing the existing breakwater A, B and C, respectively. Trucks movement during reclamation process is considered, so the removing will be started by segment A then B and will be finished by segment C.



Figure 10: Reclamation activities
(source: Callaert and Van Den Bogaert, 2016)

- Construction of bridge to connect the new offshore fishery port to the land. The final shape of new fishery port will be as in Figure 11 with a rectangular terminal.



Figure 11: The general view of proposed reclamation and bridge installation
(source: Xinhua, 2016)

4. CONCLUDING REMARKS

- The implementation of such reclamation projects can be considered as an urgent to Gaza Strip because of the increasing in population growth, the economic recession and lack of areas.
- Land reclamation in Gaza Strip is significant choice to mitigate problems of massive volume of concrete rubble that was generated from the last war on Gaza especially that almost all available landfills in the Gaza Strip are already. overloaded. On the other hand, the shortage of natural aggregate beside the high prices made the recycle of concrete rubble as one of top priority for land reclamation process.
- Sea reclamation is the best solution for many problems, especially for solving the erosion problem at areas north of existing Gaza fishery seaport. Reclamation process will permit to sediments transport to the northern direction.
- The total cost of reclaimed area of 11.4 ha is 15M USD, and the cost of one square meter of is 130 USD. Based on this result, the cost of sea reclamation is very feasible especially that Gaza fishery seaport is very vital and important place for fishery and recreation.

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